

CACHE CONTROL METHOD AND APPARATUS

1 BACKGROUND OF THE INVENTION

The present invention relates to a cache control method capable of speeding up the write process for writing data from a data processing apparatus into a storage unit by using a cache memory, and a cache control apparatus suitable for practicing the cache control method as above.

For use with information processing systems having a data processing apparatus, a control unit for a cache memory, and a storage unit, respectively interconnected together, there has been proposed the method of controlling to write a data from the data processing apparatus into the storage unit, as described for example in Japanese Laid-open Publication JP-A-55-157053.

According to a first control method described in this related art, a write process by the data processing apparatus is terminated when a data has been written in a cache memory. The data stored in the cache memory is written in the storage unit later at a proper time. This write process is called a write after process. A data written in the cache memory and not still in the storage unit is called a write after data. In this Publication JP-A-55-157053, however, there is not disclosed a detailed technology of the detailed

1 manner how a data received from the data processing unit
is written in the storage unit.

According to a second control method, the
write process by the data processing apparatus is
5 terminated only when a data has been written in the
storage unit.

According to a third control method, a write
data supplied from the data processing apparatus is
classified into a permanent write data and a temporary
10 write data. The write process for the permanent write
data by the data processing apparatus is terminated only
when the data has been written in the storage unit. On
the other hand, the write process for the temporary data
by the data processing apparatus is terminated when the
15 data has been written in the cache memory, and the
temporary data is never written into the storage unit.

Of the three control methods, the second
control method does not use a cache memory but directly
accesses the storage unit, and the third control method,
20 although it uses a cache memory, the degree of using the
cache memory is considerably limited. In view of this,
only the first control method is substantially the cache
control method capable of speeding up the write process.

However, it is difficult to apply the first
25 cache control method for writing a data from the data
processing apparatus into a record on the storage unit
if it is not stored in the cache memory at that time.

1 The reason for this is that if at the time of
writing data from the data processing apparatus, the
corresponding record is not stored in the cache memory,
then there is a possibility that the record having a
5 record number appointed by the data processing apparatus
side is not stored in the storage unit. Furthermore, if
the storage unit stores a duplicate of a record having a
record number appointed by the data processing apparatus
side, it is not possible to determine in which record
10 the data is to be written, thereby preventing a correct
write after process.

Thus, the above cache control method is hard
to be used if a record to be written is not stored in
the cache memory at the time of writing a data from the
15 data processing apparatus. Speeding up the write
process is thus impossible.

There is disclosed in JP-A-59-135563 a
technique for a disc controller with a cache memory and
a nonvolatile memory. In JP-A-59-15563, the disk
20 controller writes the data received from a data
processing unit to both the cache memory and the
nonvolatile memory. If the cache memory is breakdown
before the write after data in cache memory is written
to the disk unit, the write after data is ensured in the
25 nonvolatile memory. Therefore, the high reliable write
after process can be realized. However, there is no
consideration in the case where a record for which the

1 data processing unit issues the write request does not exist in the cache memory.

As described above, with the conventional cache control method, the write process can be speeded up on condition that a record corresponding to a data from the data processing apparatus is being stored in the cache memory at the time of data write, because the write process can be terminated when the data has been stored in the cache memory. However, if a record corresponding to the data is not being stored in the cache memory at the time of data write, it is hard to speed up the write process.

SUMMARY OF THE INVENTION

It is a first object of this invention to provide a cache control method capable of speeding up the write process even if a record to be written is not being stored in the cache memory at the time of writing a data from a data processing apparatus, by terminating the write process when the data has been stored in the cache memory.

This invention also aims at providing a cache control apparatus suitable for practicing the cache control method as above.

In order to further speed up the write process, it is necessary to efficiently execute the write process of a write after data in a storage unit. To this end, it becomes necessary, as will be later

1 described, to know the physical position of the storage
unit relative to the write after data.

It is therefore a second object of this
invention to provide a cache control method capable of
5 calculating the physical position on the storage unit
relative to the write after data when the data has been
stored in the cache memory, even if a record to be
written is not being stored in the cache memory.

This invention also aims at providing a cache
10 control apparatus suitable for practicing the cache
control method as above.

According to the present invention, the
following three cache control methods are provided in
order to achieve the first object of speeding up the
15 write process even if a record to be written is not
being stored in a cache memory.

According to the first cache control method,
in an information processing system having a data
processing apparatus, a control unit for a cache memory,
20 and a storage unit for storing a record, respectively
interconnected together, the control unit (a) receives
from the data processing apparatus a write request for a
record to be written: (b) if the record to be written is
not being stored in the cache memory, receives a data to
25 be written in the object record from the data processing
apparatus: (c) stores the received data in the cache
memory: (d) notifies the data processing apparatus of a
completion of a data write process: (e) checks if the

1 object record in which the data stored in the cache
memory is being stored in the storage unit: (f) if the
record is being stored, writes the data stored in the
cache memory in the object record of the storage unit;
5 and if not, the data stored in the cache memory is not
written and such a result is notified to the data
processing apparatus.

According to the second cache control method,
in an information processing system having a data
10 processing apparatus, a control unit for a cache memory,
and a storage unit for storing a record having a control
field inclusive of a record number, respectively
interconnected together, the control unit (a) receives
from the data processing apparatus record a write
15 request including record appointed information for
appointing a record to be written, field appointed
information for appointing a field to be written in the
record, and process mode appointed information for
appointing a process mode to be executed when the record
20 to be written is not being stored in the cache memory;
(b) if the record to be written and appointed by the
record appointed information is not being stored in the
cache memory and if the field to be written and
appointed by the field appointed information does not
25 contain the control field, then receives from the data
processing apparatus a data to be written in the
appointed field in accordance with the process mode
appointed by the process appointed information; (c)

1 stores the data in the cache memory; and (d) notifies
the data processing apparatus of a completion of a write
process.

According to the third cache control method,
5 in an information processing system having a data
processing apparatus, a control unit for a cache memory,
and a storage unit for storing a record having a
plurality of physical areas for storing a record having
a control field inclusive of a record number, respec-
10 tively interconnected together, the control unit holds,
for each physical area, structural condition information
which represent as to whether "there is no duplicate
record number of the record in the physical area" is
satisfied or not, (a) receives from the data processing
15 apparatus a write request including record appointed
information for appointing a record to be written, and
field appointed information for appointing a field to be
written in the record; (b) if the record to be written
and appointed by the record appointed information is not
20 being stored in the cache memory, if the field to be
written and appointed by the field appointed information
does not contain the control field, and if the structur-
al condition is satisfied, then receives from the data
processing apparatus a data to be written in the
25 appointed field in accordance with the process mode
appointed by the process appointed information; (c)
stores the data in the cache memory; and (d) notifies
the data processing apparatus of a completion of a

1 write process.

Next, the following two cache control methods are provided as the fourth and fifth cache control methods in order to achieve the second object of making 5 possible to calculate the physical position of a storage unit relative to a write after data even when a record to be written is not being stored in a cache memory.

According to the fourth cache control method, in an information processing system having a data 10 processing apparatus, a control unit for a cache memory, and a storage unit for storing a record having a plurality of physical areas for storing a record having a control field inclusive of a record number, respectively interconnected together, the control unit (a) 15 receives from the data processing apparatus a write request including record appointed information for appointing a record to be written, field appointed information for appointing a field to be written in the record, and structural condition information which 20 represents as to whether "the record number of the record at the start of the physical area for storing records is "0" and the numbers of following records are given in the ascending order each incremented by "one", each record has one field other than the control field, 25 the length of the field other than the control field of each record having the record number 1 or larger is the same, and the field other than the control field of the record having the record number 0 has a predetermined

1 length" is satisfied or not; (b) if the record to be
written and appointed by the record appointed informa-
tion is not being stored in the cache memory, if the
field to be written and appointed by the field appointed
5 information does not contain the control field, and if
the structural condition is satisfied, then receives
from the data processing apparatus a data to be written
in the appointed field; (c) stores the data in the cache
memory; and (d) notifies the data processing apparatus
10 of a completion of a write process.

According to the fifth cache control method,
in an information processing system having a data
processing apparatus, a control unit for a cache memory,
and a storage unit for storing a record having a
15 plurality of physical areas for storing a record having
a control field inclusive of a record number, respec-
tively interconnected together, the control unit holds,
in each physical area, structural condition information
represents as to whether "the record number of the
20 record at the start of the physical area for storing
records is "0" and the numbers of following records are
given in the ascending order each incremented by "one",
each record has one field other than the control field,
the length of the field other than the control field of
25 each record having the record number 1 or larger is the
same, and the field other than the control field of the
record having the record number 0 has a predetermined
length" is satisfied or not, (a) receives from the data

1 processing apparatus a write request including record
appointed information for appointing a record to be
written, and field appointed information for appointing
a field to be written in the record; (b) if the record
5 to be written and appointed by the record appointed
information is not being stored in the cache memory, if
the field to be written and appointed by the field
appointed information does not contain the control
field, and if the structural condition is satisfied,
10 then receives from the data processing apparatus a data
to be written in the appointed field; (c) stores the
data in the cache memory; and (d) notifies the data
processing apparatus of a completion of a write process.

The present invention provided the cache
15 control apparatus provided with means for practicing the
first to fifth cache control methods.

According to the first cache control method of
this invention, even if a data to be written and
supplied from the data processing apparatus is not being
20 stored in the cache memory, the data is stored in the
cache memory and a completion of the write process is
notified to the data processing apparatus at this stage.
A write after data in the cache memory is written in the
storage unit by means of the write after process. If
25 the record to be written is not present in the storage
unit, such a result is notified. In the above manner,
the write process can be speeded up irrespective of

1 whether or not a data from the data processing apparatus
is being stored in the cache memory.

According to the second and fourth cache
control methods of this invention, upon reception of a
5 write request from the data processing apparatus, a data
to be written and supplied from the data processing
apparatus is stored by a control unit in the cache
memory even if the data is not being stored in the cache
memory, and the control unit notifies a completion of
10 the write process to the data processing apparatus at
this stage.

According to the third and fifth cache control
methods of this invention, if a data to be written and
supplied from the data processing apparatus is not being
15 stored in the cache memory, the control unit checks if
there is not duplicated record number in the storage
unit, and then stores the data in the cache memory and
notifies a completion of the write process at this
stage. Therefore, an occurrence of error during the
20 write after process can be avoided and the write process
can be speeded up. In order to check a duplicated
record number, the data processing apparatus holds
therein the information represents as to whether or not
there is a duplicated record number in the storage unit.

25 According to the fourth and fifth cache
control methods of this invention, the physical position
of the storage unit relative to the write after data can
be calculated in accordance with the structural informa-

1 tion such as the ascending order of record numbers,
thereby further improving the efficiency of the write
process.

5 The cache control apparatus embodying the
first to fifth cache control methods operate in the same
manner as described above.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of the control unit
according to the first embodiment of this invention.

10 Fig. 2 is a block diagram of the information
processing system according to the present invention;

Fig. 3 shows the structure of the disk unit
24;

15 Fig. 4 shows an example of the structure of
the record 301;

Fig. 5 shows an example of another structure
of the record 301;

20 Fig. 6 shows an example of the structure of
the cache memory 26 according to the first embodiment of
this invention;

Fig. 7 shows an example of the structure of
the segment according to the first embodiment of this
invention;

25 Fig. 8 shows an example of the structure of
the directory 28 according to the first embodiment of
this invention;

1 Fig. 9 shows an example of the structure of
the segment management information 500 according to the
first embodiment of this invention;

5 Fig. 10 shows an example of the structure of a
track table 501 according to the first embodiment of
this invention;

Fig. 11 illustrates the empty segment queue
head pointer 502 according to the first embodiment of
this invention;

10 Fig. 12 shows an example of the structure of
the write after memory 27 according to the first
embodiment of this invention;

15 Fig. 13 shows an example of the structure of
the write after information 1100 according to the first
embodiment of this invention;

Fig. 14 shows an example of the structure of
the director 25 of the first embodiment of this
invention;

20 Fig. 15 is a flow chart illustrating the
processes to be executed by the cache partial write part
10 according to the first embodiment of this invention;

Fig. 16 is a flow chart illustrating the
processes to be executed by the write after schedule
part 11;

25 Fig. 17 is a flow chart illustrating the
processes to be executed by the write after transfer
part 12 according to the first embodiment of this
invention;

1 Fig. 18 is a flow chart illustrating the
processes to be executed by the write after error
decision part 13;

5 Fig. 19 is a block diagram showing the
fundamental structure of the control unit according to a
second embodiment of this invention;

Fig. 20 shows an example of the structure of
the write after memory 27 according to the second
embodiment of this invention;

10 Fig. 21 shows an example of the structure of
the write after track information a 1700 according to
the second embodiment of this invention;

Fig. 22 is a state transition diagram of the
track state a 1800 according to the second embodiment of
15 this invention;

Fig. 23 shows an example of the structure of
director 25 according to the second embodiment of this
invention;

20 Figs. 24A and 24B are flow charts illustrating
the processes to be executed by the write after track
information management part a 14 according to the second
embodiment of this invention;

25 Fig. 25 is a flow chart illustrating the
processes to be executed by the write after information
management part b 15 according to the second embodiment
of this invention;

Fig. 26 is a block diagram showing the
fundamental structure of the control unit 23 according

1 to a third embodiment of this invention;

Fig. 27 shows an example of the structure of the segment management information 500 according to the third embodiment of this invention;

5 Fig. 28 shows an example of the structure of the write after information 1100 according to the third embodiment of this invention;

Fig. 29 is a flow chart illustrating the processes to be executed by the cache partial write part 10 according to the third embodiment of this invention;

Fig. 30 is a flow chart illustrating the processes to be executed by the write after schedule part 11 according to the third embodiment of this invention;

15 Fig. 31 is a flow chart illustrating the processes to be executed by the write after transfer part 12 according to the third embodiment of this invention;

Fig. 32 is a flow chart illustrating the processes to be executed by the write after error decision part 13 according to the third embodiment of this invention;

20 Figs. 33 and 34 conceptually illustrates the method of efficiently writing the write after record 25 160;

Fig. 35 is a block diagram showing the fundamental structure of the control unit 23 according to a fourth embodiment of this invention;

1 Fig. 36 shows an example of the structure of
the write after memory 27 according to the fourth
embodiment of this invention;

5 Fig. 37 shows an example of the structure of
the write after track information b 2800 according to
the fourth embodiment of this invention;

Fig. 38 is a state transition diagram of the
track state b 2900 according to the fourth embodiment of
this invention;

10 Fig. 39 is a flow chart illustrating the
processes to be executed by the cache partial write part
10 according to the fourth embodiment of this invention;

15 Figs. 40A and 40B are flow charts illustrating
the processes to be executed by the write after track
information management part a 14;

Fig. 41 is a flow chart illustrating the
processes to be executed by the write after track
information management part b 15 according to the fourth
embodiment of this invention;

20 Fig. 42 shows an example of the relationship
between records 301 on the track 300 at consecutive
positions, and records stored in the segment 400 at
consecutive positions;

25 Figs. 43A, 43B, and 43C show examples of
segments 400 used for explaining the consecutive storage
conditions;

1 Fig. 44 shows an example of the structure of
the segment management information 500 according to a
fifth embodiment of this invention; and

5 Fig. 45 illustrates the outline of this
invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of this invention will
be described below.

10 The embodiments of this invention include
first to fifth embodiments. The common elements thereto
will first be described with reference to Figs. 2 to 5.

Fig. 2 is a block diagram showing an informa-
tion processing system embodying the present invention.

15 The information processing system is
constructed of a data processing unit 200, a control
unit 23, and one or more disk units 24, all operatively
connected to each other.

20 The data processing unit 200 has a CPU 20, a
main storage 21, and channels 22.

25 The control unit 23 has one or more directors
25, a cache memory 26, a write after memory 27, and a
directory 28.

25 The director 25 performs data transfer between
the channel 22 and the disk unit 24, between the channel
22 and the cache memory 26, and between the cache memory
26 and the disk unit 24.

1 The cache memory 26 is loaded with the data of
the disk unit 24 frequently accessed. This load process
is executed by the director 25. Particular examples of
such data includes the data accessed in the past by CPU
5 20, the data stored in the disk unit 24 at areas near
the data accessed by CPU 20, and other data.

 The director 28 stores management information
for the cache memory 26.

 The disk unit 24 has the structure as shown in
10 Fig. 3A. Each disk unit 24 has a plurality of disks
308, each disk being a medium for storing data. A
read/write head 309 for reading/writing data relative to
the disk 308 is provided for each disk 308.

 A circular area accessible by the read/write
15 head 309 while the disk 308 rotates once, is called a
track 300. A plurality of tracks 300 are formed on the
disk 308. When the data is read from or written in the
track 300, the read/write head 309 is moved to the
position where the data can be read/written. This
20 operation is called a seek operation. A request for
such an operation is called a positioning request. A
director interface 311 is an interface between the disk
unit 24 and the director 25, the interface 311 controlling
the read/write head 309 in accordance with an
25 instruction from the director 25.

 Sectors 302 are areas formed on the disk 308
at a predetermined angle interval from a reference
position 303 of the disk 308. This reference position

1 303 is called a home index 303. The sector 302 starting
from the home index 303 is called a basic sector 304
(sector 0). The number of each sector 302 is
incremented by one from the basic sector 304 in the
5 direction opposite to the rotation of the disk 308.

The read/write head 309 identifies the sector
302 positioned under it.

Immediately after the home index 303, there is
formed an area which stores control information for the
10 track 300. This area is called a home address 306.

Each track 300 has one or more records 301.

The record 301 is a unit of data read from or written in
the disk unit 24 by the director 25.

A gap 305 is formed between adjacent records
15 301. The gap 305 between the records 301 is called a
gap a 305 in order to discriminate from a gap b 605
(refer to Figs. 4 and 5) to be described later.

Each record 301 may have a different length.
The length of each gap a is the same.

20 Generally, the record 301 immediately after
the home address 306 stores not general data, but
control data to be used by CPU 20 side. Therefore, this
record is called a control record 310.

Figs. 4 and 5 show examples of the structure
25 of the record 301. In the example shown in Fig. 4, the
record 301 is constructed of three fields 606 including
a control field 600, a key field 607, and a data field
601. In the example shown in Fig. 5, the record 301 is

1 constructed of two fields 606 including a control field
600 and a data field 601.

5 A gap 605 is formed between the control field
600 and the key field 607, and between the key field 607
and the data field 601. This gap 605 is called the gap
b 605. The length of each gap b 605 is the same.

10 The control field 600 records control informa-
tion including a record number 602, a key field length
608, a data field length 603 and the like. The record
number 602 is a discriminator for the record 301. The
key field length 608 and data field length 603 represent
the length of the key field 607 and data filed 601,
respectively. If the record 301 has no key field 607 as
shown in Fig. 5, the key field length 608 is set to 0.
15 The length of the control filed 600 is generally fixed.

The data field 601 records information to be
processed by a program running on CPU 20.

20 The key field 607 records key information
which checks the right of accessing to the contents of
the data field 601.

25 A write process generally includes a format
write process and a partial write process. The former
process is for altering all the fields 606 inclusive of
the control field 600, and the latter process is for
altering the fields excepting the control field 600.
The execution frequency of the format write process is
not so high and no necessary to speed up because it is
executed only when a whole file is made first time. The

1 execution frequency of the partial write process is high
so that it should be speeded up. Therefore, this invention
mainly relates to a partial write.

2 The data field length 603 and key field length
5 608 are present within the control field 600. Therefore,
with the partial write process, the contents of
the data field 601 and the key field 607 change, but the
length in the control field 600 maintains unchanged.

3 The process outline of the present invention
10 will be given.

4 Fig. 45 shows the outline of the operation of
each processing unit, i.e., the outline of this invention.
A cache partial write part 10 first receives a
5 partial write request from CPU 20 via the channel 21.
In this case, even if a record to be written is not
present in the cache memory 26 (even if a record 301
15 having a record number 602 appointed by CPU 20 for data
write is not present in the cache memory 26), the cache
partial write part 10 executes the following cache write
20 process. Namely, a data to be written in the record 301
appointed by CPU 20 is stored in the cache memory 25 as
a write after data 29. After completion of data
storage, a completion of the partial write request is
25 notified to CPU 20 side.

26 Next, a write after schedule part 11 determines the track 300 of the disk unit 24 with respect to
which the write after process is to be executed, and
issues a positioning request to the disk unit 24.

1 After completion of the positioning process, a
write after transfer part 12 finds a disk 301 in which
the write after data 29 stored in the cache memory 26 is
to be stored (i.e., the part 12 finds the record 301
5 having the record number 602 appointed by CPU 20). If
the record is found, there is executed the write after
process for writing the write after data 29 in the
record 301. If not, the write after process is not
executed, but record number inconsistent information
10 1202 in write after information 1100 is set to thereby
memorize an occurrence of an error.

 Lastly, a write after error decision part 13
refers to the record number inconsistent information
1202 to notify to CPU 20 of the fact that the record 301
15 to be written with the write after data 29 was not found
in the disk unit 24. In the following embodiments, the
write after error decision part 13 sends such an error
notice to CPU 20 when the former receives a read/write
request from the latter. However, timings of giving
20 such an error notice are not limited thereto, but other
timings may also be used. For example, an error notice
may be given to CPU 20 immediately after the write after
transfer part 12 sets the record number inconsistent
information 1202 in the write after information 1100.

25 Next, the first embodiment of this invention
will be described with reference to Figs. 1, 6 to 18.
In the first embodiment, if a record 301 to be written
is not present in the cache memory 26, and only when the

1 director 25 receives a particular process mode appointed
by CPU 20, the director 25 terminates the write process
when the data has been written in the cache memory 26.

Fig. 1 is a diagram illustrating in detail the
5 information processing system of the first embodiment.

The director 25 receives the following
appointed information a 100 from CPU 20 via the channel
22 during the course of executing the partial write
process.

10 Appointed Information 1 ... for appointing the
disk unit 24 and the track 300 storing the record 301 to
be written.

Appointed Information 2 ... for appointing the
sector 302 of the track 300 from which the record 301 to
15 be written is searched.

Appointed Information 3 ... for appointing the
record number 602 of the record 301 to be written.

Appointed Information 4 ... for appointing the
field 606 to be written.

20 Appointed Information 5 ... for appointing a
process mode when the record 301 to be written is not
being stored in the cache memory 26. Namely, when CPU
20 recognizes that there is no duplicated record number
602 in the track 300 appointed by the appointed
25 information 1, this process mode is appointed for
terminating the write process when the data has been
written in the cache memory 26.

1 Thus, the execution condition a 110 of the
cache write operation 100 according to this invention is
that the record 301 to be written is not being stored in
the cache memory 26, the field to be written does not
5 contain the control field 600, and the process mode
appointed by the appointed information 5 has been
received.

10 In the cache write operation 120, the director
25 receives a data from the channel 22 (step 121), and
writes the received data in the cache memory 26 (step
122). A notice of write process completion is given via
15 the channel 22 to CPU 20 (step 123).

20 A data stored in the cache memory 26 and not
written in the disk unit 24 is called a write after data
15 29.

25 The director 25 manages the record 301 which
stores the write after data 29, as a write after record
160.

30 The director 25 writes the write after data 29
in the disk unit 24 by using an idle time of the
director 25. This operation is called a write after
operation.

35 In a write after operation a 130, the director
25 finds the record 301 on the disk unit 24 where the
25 write after data 29 is written. Specifically, the
director 25 finds the record 301 having the record
number 602 appointed by the appointed information 3
within the track 300 of the disk unit 24 appointed by

1 the appointed information 1 and 2.

If the object record 301 has been found, the director 25 executes a write after operation b 140 to write the write after data 29 in the record 301.

5 If the object record 301 is not found, the director 25 executes a write after operation c 150 not to write the write after data 29, and notifies to CPU 20 of such a situation as will be described later.

Fig. 6 shows the structure of the cache memory
10 26 of this embodiment.

The cache memory 26 is constructed of a number of segments 400.

Each segment 400 can store all records 301 of one track 300. A conventional method may be used as a
15 method of determining which segment 400 is allocated to which track 300. An empty segment 400 may be present which has not been allocated with the track 300.

Fig. 7 shows the storage format of the write after data 160 within the segments 400.

20 Since the data in the control field 600 is not changed at the partial write process, the director 25 does not receive the control field 600 from the channel 22. Thus, if the record 301 to be written is not being stored in the cache memory 26 and the supplied data has
25 been written, the director 25 forms a dummy control field 1000 in the cache memory 26.

The appointed record number 602 from the channel 22 is stored in the dummy record field 1000.

1 Also stored in the dummy record field 1000 is the length
of the data to be written in the appointed field 606 and
supplied from the channel 22. If the contents of the
key field 607 and data field 601 are to be changed, the
5 length of the data for the respective fields is set as
the key field length 608 and data field length 603. If
the contents of the data field 601 only are to be
changed, 0 is set as the key field length 608. In the
following description, the key field length 608 and data
10 field length 603 are collectively called a field length
609.

For writing the write after record 160 in the
record 301 of the disk unit 24, the director 25
determines whether or not the write after process is to
15 be executed, by comparing the record number 602 and
field length 609 in the control field 600 of the record
301 on the disk unit 24 with the corresponding record
number 602 and field length 609 in the dummy control
field 1000.

20 If the record 301 to be written is being
stored in the cache memory 301, the control field 600
has been already stored in the segment 400 so that the
dummy control field 1000 is not formed.

After the dummy control field 1000 or control
25 field 600, there are stored a key field pointer 1001, a
data field pointer 1002, and a dummy control field flag
1003.

The key field pointer 1001 and data field

1 pointer 1002 are the pointers to the key field 607 and
data field 601 stored in the cache memory 26, respec-
tively. The reason for providing these pointers is that
there is a case where areas for storing one write after
5 data 160 are not consecutive. An example of such a case
will be described in the following. When the director
25 receives the partial write request for only the data
field 601 of the record 301 not stored in the cache
memory 26, an area for storing the key field 607 cannot
10 be established because the length of the key field 607
cannot be known. Therefore, the key field length 608 is
set to 0. Thereafter, it is assumed that there is
received the partial write request for changing the
contents of both the key field 607 and data field 601.
15 In this case, the length of the key field 607 is known
so that the area for the key field 607 is established at
this stage. Accordingly, as shown in Fig. 7, the area
for the key field 607 is established at the position
remote from the write after record 160 containing the
20 dummy control field 1000, so that the areas for storing
one write after record 160 are not contiguous.

The dummy control field flag 1003 is turned on
when the director 25 has generated the dummy control
field 1000, whereas it is turned off when the director
25 has loaded the record 301 from the disk unit 24 to
the cache memory 26.

Fig. 8 shows information provided within the
directory according to this embodiment. The information

1 includes segment management information 500, a track
table 501, and an empty segment queue head pointer 502.
The segment management information 500 is provided for
each segment 400. One track table 501 and one empty
5 segment queue pointer 502 are provided within the
directory 28.

Fig. 9 shows information provided as the
segment management information 500 according to this
embodiment.

10 An empty segment pointer 800 ... a pointer to
the segment management information 500 for another empty
segment 400.

15 A partial write flag 801 ... a flag indicating
that the write after data 29 written upon the partial
write request is being stored in the segment 400
corresponding to the segment management information 500
in concern.

20 A cached track number 805 .. the number of the
track 300 stored in the segment 400 corresponding to the
segment management information 500 in concern.

25 A record pointer 806 ... a pointer to the
record 301 stored in the segment 400 corresponding to
the segment management information 500 in concern. For
example, the n-th record pointer 806 is a pointer to the
record 301 having the record number 602 (n-1). If the
record 301 having the record number 602 (m-1) is not
being stored in the cache memory 26, the m-th record
pointer 806 takes a null value. In this example, it is

1 assumed that the top record pointer 806 is a pointer to
the record 301 having the record number 0. The number
of record pointers 806 is as many as the number of
record numbers 602 which can be defined within one
5 track 300.

An updated record pointer 807 ... a pointer to
the write after record 160 stored in the segment 400
corresponding to the segment management information 500
in concern. In this case, even if the partial write
10 process is for the record 301 already stored in the
cache memory 26, the director 25 manages this record 301
as the write after record 160. Similar to the record
pointer 806, the n-th updated record pointer 807 is a
pointer to the record 301 having the record number 602
15 (n-1). If the record 301 having the record number 602
(m-1) is not a write after record 160, the m-th updated
record pointer 807 takes a null value. The number of
updated record pointers 807 is also as many as the
number of record numbers 602 which can be defined within
20 one track 300.

Updated field information 808 ... information
indicating the updated field 606 in the write after
record 160 having the record number n. Namely, the
information indicates which combination of the record
25 field 600, key field 607, and data field 601 constitutes
the updated fields. The number of updated field
information 808 is also as many as the number of record
numbers 602 which can be defined within one track 300.

1 An intra-segment empty area address 809 ... an
address indicating the start address of an empty area
not storing the record 301 within the segment 400
corresponding to the segment management information 500
5 in concern.

 A segment pointer 810 ... a pointer to the
segment within the cache memory 26 corresponding to the
segment management information 500 in concern.

Fig. 10 shows the structure of the track table
10 501. The track table 501 stores information regarding
whether or not each track of all disk units 24 is
assigned the segment 400. If the segment is assigned to
the track, the information of the track table 501 is a
pointer to the segment management information 500
15 corresponding to the assigned segment. If not, the
information takes a null value. In the track table 501,
the information of the tracks 300 of the same disk unit
24 is stored in a sequential order of the track number.

As shown in Fig. 11, the segment management
20 information 500 for the empty segments 400 is first
identified by the empty segment queue head pointer 502
and then sequentially interconnected by the empty
segment pointers 800 for the corresponding segment
management information 500.

25 Fig. 12 shows the structure of the write after
memory 27 which stores write after information 1100 for
each disk unit 24. The write after information 1100

1 includes information representative of an execution
state of the write after process, and error information.

Fig. 13 shows the information stored in each
write after information 1100. The information stored in
5 each write after information 1100 will be described
below.

A write after processing flag 1200 ... a flag
indicating if the disk unit 24 corresponding to the
write after information 1100 in concern is executing the
10 write after process.

A write after segment pointer 1202 ... a
pointer to the segment management information 500
corresponding to the track 300 subjected to the write
after process.

15 Record number inconsistent information
1203 ... information representative of the record number
602 of the record 301 subjected to the write after
process, the record 301 being not stored in the disk
unit 24.

20 Field length inconsistent information 1204 ...
information representative of the field 606 subjected to
the write after process, the length of the field 606
being inconsistent.

If the record number inconsistent information
25 1203 or field length inconsistent information 1204 is
present, it means that an error has occurred during the
write after process. An error may occur because of
other reasons. However, such an error is not directly

1 associated with the present invention, the description
therefor is omitted.

The above information may be erased by power failure or the like so that the information is 5 preferably stored in a non-volatile manner.

Fig. 14 shows the structure of the director 25 according to this embodiment. Each part will be described below.

A cache partial write part 10 ... upon
10 reception of a partial write request, it transfers a
data received from the channel 22 to the cache memory
26.

A write after schedule part 11 ... it determines the disk unit 24 and track 300 to be subjected to the write after process.

A write after transfer part 12 ... it executes the write after process scheduled by the write after schedule part 11.

20 A write after error decision part 13 ... upon reception of an input/output request from CPU 20, it checks if there occurs an error at the disk unit 24 to which the request was directed, in the write after process. If an error occurs, such a situation is sent via the channel 22 to CPU 20.

25 The operation of each part will be described
below.

Fig. 15 is a flow chart illustrating the processes to be executed by the cache partial write part

1 10. This process flow includes also a process for the
case the record 301 to be written is already stored in
the cache memory 26. This process flow is executed when
the director 25 receives a partial write request from
5 CPU 20 via the channel 22, the partial write request
including the appointed information 5 for appointing a
process mode by which even if the record 301 to be
written is not being stored in the cache memory 26, the
write process is completed when the data has been stored
10 in the cache memory 26.

At step 1300, it is checked if the segment 400
has already been allocated to the track 300 to be
written. This check relies on the track table 501
corresponding to the track 300 in concern. If the
15 segment 400 is not still allocated, the process flow
advances to step 1301. If already allocated, the
process flow jumps to step 1305.

At step 1301, the segment 400 and segment
management information 500 are allocated to the track
20 300 in concern. The allocation method may use a known
method.

At step 1302, the allocated segment
information 500 is initialized. This initialization
includes, for example, a process of setting the track
25 number of the track 300 to be written, as the cached
track number 805.

At step 1303, by using the record number
appointed by the appointed information 3, the dummy

1 control field 100 is formed.

At step 1304, the data received from the channel 22 is stored in the area corresponding to the field 606 appointed by the appointed information 4.

5 Thereafter, the process flow advances to step 1311.

At step 1311, the necessary portion of the segment management information 500 is updated, and a completion of the write process is notified to CPU 20 via the channel 22 to thereafter terminate the write

10 process.

On the other hand, if affirmative at step 1300, it is checked at step 1305 if the record 301 to be written is being actually stored in the cache memory 26.

This is carried out by referring to the segment management information 400 and checking whether or not the record pointer 806 to the record number 602 in concern takes a null value. If the record 301 to be written is not actually stored in the cache memory 26, the process

flow jumps to step 1303 and thereafter, executes the processes the same as for the case where the segment 400 has not been allocated to the track 300 to be written.

If the record 301 to be written is actually being stored in the cache memory 26, the process flow advances to step 1306.

25 At step 1306, it is checked if all the fields 606 appointed by the appointed information 4 from CPU 4 are stored in the cache memory 26. If they are stored, the process flow advances to step 1308. If not, the

1 process flow advances to step 1307.

At step 1307, it is checked if the dummy control field flag 1003 for the record 301 to be written is on or off. If off, it means that the record 301 to be written was loaded in the cache memory 26 from the track 300. Therefore, this case contradicts the check results at step 1306 that all the fields 606 have been stored. The process flow therefore jumps to step 1313 to issue an error notice. If the dummy control field flag 1003 is on, then the process flow advances to step 1312.

At step 1312, the data received from the channel 22 is stored in the areas corresponding to the fields 606 already stored and newly established. The length of the data newly stored in the cache memory 26 is stored as the key field length 608 or data field length 603 within the dummy control field 1000. A proper value is set to the key field pointer 1001 or data field pointer 1002. Thereafter, the process flow advances to step 1309.

On the other hand if affirmative at step 1306, the data received from the channel 22 is stored in the cache memory 26 at the area corresponding to the field 606.

At step 1309 it is checked if the stored data in the cache memory 26 at the area corresponding to the field 606 is consistent with the key field length 608 or data field length 603 within the control field 600. If

1. consistent, the process flow advances to step 1311. If not, the process flow 1310 advances to step 1310.

At step 1310, the data length inconsistency is notified to CPU 20 via the channel 22 to thereafter 5 terminate the process.

On the other hand if negative at step 1307, the director 25 notifies at step 1313 to CPU 20 via the channel 22 of the fact that there is contradiction with respect to the field 60 to be written to thereafter 10 terminate the process.

Fig. 16 is a flow chart illustrating the processes to be executed by the write after schedule part 11. This process flow includes also a process of writing in the disk unit 24 the write after data 29 15 contained in the record 301 stored in the cache memory 26.

This process flow is executed by the director 25 during the idle time. Namely, upon reception of a partial write request, the data stored in the cache 20 memory is written in the disk unit 24.

The disk unit 24 to be written is the disk unit of which the write after processing flag 1200 is off and to which an input/output request is not acknowledged. The track 300 to be written in the write 25 after process is a track corresponding to the segment management information 500 whose partial write flag 801 is on.

First at step 1400, the write after processing

1 flag 1200 of the write after information 1100 of the
disk unit 24 to be operated, is turned on, and a pointer
to the segment management information 400 for the track
300 to be written is set as the write after segment.
5 pointer 1202.

At step 1401, a positioning request for the
track 300 to be written is supplied to the disk unit 24
to be operated, to thereafter terminate the process
flow.

10 Fig. 17 is a flow chart illustrating the
processes to be executed by the write after transfer
part 12. This process flow includes also a process of
writing in the disk unit 24 the write after data
contained in the record 301 stored in the cache
15 memory 26.

This process flow is executed after the
positioning request for the disk unit generated by the
write after schedule part 11 has been completely carried
out.

20 At step 1500 it is checked if all the write
after records 1600 have been completely written in the
object track 300. If there is no null value in all the
update record pointers 807 in the segment management
information 500 pointed by the write after segment
25 pointer 1202, it means that the write after record 160
has been completely written. If there is a null value,
it means that all the write after record 160 is not
written. If completed, the process flow jumps to step

1 1509. If not, the process flow advances to step 1501.

At step 1501, the record 301 of the track 300 starts to be searched, while storing the physical position of the track 300 from which the search started.

5 The stored physical position is used to check one revolution of the track 300.

At step 1502, the control field 600 of the record 301 on the track 300 is read.

At step 1503, the record number 602 within the 10 read-out control field 600 is compared with the record number 602 within the dummy control field 1000 or control field 600 pointed by the update record pointer 807. If both the record numbers 602 are coincident, it means that the record 301 now accessed is to be used for 15 the write after process so that the process flow advances to step 1504. If not, the process flow advances to step 1507.

At step 1504, the field 606 to be written is detected by using the update field information 808 20 corresponding to the update record pointer 807. The length of the detected field 606 is derived from the key field length 608 or data field length 603 within the dummy control field 1000 or control field 600. The derived length is compared with the key field length 608 25 or data field length 603 within the control field 600 read from the track 300 at step 1502, to check if they are coincident. If not coincident, the process flow advances to step 1506 without writing the data. If

1 coincident, the process flow advances to step 1505. At
step 1505, the write after data 29 for the field 606 to
be written is read from and written in the accessed
record 301 on the track 300 to thereafter return to step
5 1500.

At step 1506, there is set the field length
inconsistent information 1204 of the write after
information 1100 to thereafter advance to step 1510.

At step 1507 it is checked if the record 301
10 to be written has underwent one revolution search for
the track 300. If not, the process flow returns to step
1502 continue the search. If one revolution search has
been completed, the process flow advances to step 1508.

At step 1508, there is set the record number
15 inconsistent information 1203 to thereafter advances to
step 1510.

At step 1509, the segment management
information 400 is updated which has become necessary to
be updated upon completion of the write after process.

20 At step 1510 the write after processing flag
1200 is reset to thereafter terminate the process flow.

Fig. 18 is a flow chart illustrating the
processes to be executed by the write after error
decision part 13.

25 This process flow is executed when an
input/output request is received from CPU 20 via the
channel 22.

1 It is checked at step 1600 whether or not
there is being set the record number in consistent
information 1204 or field length in consistent
information 1204 of the write after information 1100 for
5 the object disk unit 24. If neither the inconsistent
information 1203 nor 1204 is being set, the process flow
terminates. If at least one of the inconsistent
information 1203 or 1204 is being set, then the process
flow advances to step 1601.

10 At step 1601, an error notice is given to CPU
20 to thereafter terminate the process flow.

Next, the second embodiment will be described
with reference to Figs. 19 to 25. According to this
embodiment, in the case where the record 301 to be
15 written is not being stored in the cache memory 26, the
director 25 executes a check operation based on the
information held in the control unit 23 and the write
process is completed when the data has been written in
the cache memory 26.

20 Fig. 19 is a detailed block diagram showing
the information processing system of this embodiment.
The different points of this embodiment from the first
embodiment shown in Fig. 1 are as follows. First, the
write after memory 27 stores therein write after track
25 information a 1700 indicating whether or not each track
300 contains a duplicated record number. Second, the
appointed information b 3300 from CPU 20 does not
contain the appointed information 5 which appoints a

1 process mode for the case where the record to be written
301 is not being stored in the cache memory 26. Third,
the execution condition b 3310 of the cache write
operation 120 contains a condition that the track 300 to
5 be written does not contain a duplicated record number.
The other structure is the same as the first embodiment
shown in Fig. 1. The following description is given
while paying attention mainly to the different points
from the first embodiment.

10 Fig. 20 shows the structure of the write after
memory 27 of this embodiment. The difference from the
write after memory 27 of the first embodiment shown in
Fig. 12 resides in that the write after memory 27 of
this embodiment stores there in the write after track
15 information a 1700 provided for each disk unit 24.

Fig. 21 shows the structure of the write after
track information a 1700. The write after track
information a 1700 includes track state information a
1800 representative of one of three states, a state that
20 there is no duplicated record number, a state that there
is a duplicated record number, and a state that it is
not certain if there is a duplicated record number. The
track state a 1800 of each track 300 is stored in the
order of track number.

25 Fig. 22 shows a state transition of the track
state a 1800. The track state a 1800 initially takes a
state 391 that it is not certain if the track 300 has a
duplicated record number. Upon reception of a partial

1 write request in this state 391, the director 25 checks
if the track 300 has a duplicated record number or not.
If there is no duplicated record number, the track state
a 1800 is set to a state 392 that there is no duplicated
5 record number. If there is a duplicated record number,
the track state a 1800 is set to a state 393 that there
is a duplicated record number. If a format write
request is received, the director 25 causes the track
state a 1800 to take the state 391 that it is not
10 certain if there is a duplicated record number or not.
The reason for this is that there is a possibility that
the record number 602 of the record may be changed by
the format write process.

The cache memory 26, storage format of the
15 segment 400, directory 28, segment management
information 500, track table 501, and empty segment
queue head pointer 502 all have the same structure as
the first embodiment, respectively shown in Figs. 6, 7,
8, 9, 10, and 11.

20 Fig. 23 shows the structure of the director 25
of this embodiment. The different points from the
director 25 of the first embodiment shown in Fig. 1 are
that the director 25 of this embodiment has the
following two parts.

25 A write after track information management
part a 14 ... this part operates in the following
manner. When a partial write request is received for
the track 300 whose track state a 1800 takes the state

1 391 that it is not certain if the track 300 has a
duplicated record number or not, this part checks if the
track 300 has a duplicated record number or not, and the
check result is stored as the track state a 1800.

5 A write after track information management
part b 15 ... this part operates in the following
manner. When a format write request is received for the
track 300, this part causes the track state a 1800 of
the track 300 to take the state 391 that it is not
10 certain if there is a duplicated record number or not.

15 The process flows for the cache partial write
part 10, write after schedule part 11, write after
transfer part 12, and write after error decision part 13
are the same as those shown in Figs. 15 to 18, except
that the flow process of the cache partial write part 10
15 becomes executable in the manner different from the
first embodiment. Namely, in this embodiment, the flow
process of the cache partial write part 10 is allowed to
be executed only when the track state a 1800 of the
20 track 300 to be subjected to the partial write request
from CPU 20 takes the state 392 that there is no
duplicated record number.

25 Figs. 24A and 24B are flow charts to be
executed by the write after track information management
part a 14.

 The process flow shown in Fig. 24A is allowed
to be executed when the director 25 receives a partial
write request for the track 300 whose track state a 1800

1 takes the state 391 that it is not certain if there is
a duplicated record number.

At step 2000, a positioning request is issued
to the track 300 to which the partial write request was
5 directed, to thereafter terminate the process flow.

The process flow shown in Fig. 24B is allowed
to be executed when the positioning request issued at
step 2000 has been completed.

At step 2001, it is checked if there is a
10 duplicated record number, by reading all records 301 on
the track 300 to which the partial write request was
directed.

At step 2002, the check result is stored in
the track state a 1800 of the track 300 in concern, to
15 thereafter terminate the process flow.

Fig. 25 is a flow chart to be executed by the
write after track information management part b 15.

This process flow is allowed to be executed
when the director 25 receives a format write request.

20 At step 2100, the track state a 1800 of the
track 300 to be subjected to the format write process is
caused to take the state 391 that it is not certain if
there is a duplicated record number or not, to there-
after terminate the process flow.

25 The third embodiment will be described next
with reference to Figs. 26 to 34. According to the
third embodiment, if the record 301 to be written is not
being stored in the cache memory 26 and only when

1 specific appointed information is received from CPU 20,
the data is written in the cache memory 26 and the write
process is completed at this stage. Moreover, the
efficiency of the write after process is intended to be
5 improved by calculating the physical write position on
the track 300 of the record 301 to be written.

In the following there will be described the
reason why the write after process efficiency is
improved by calculating the physical write position.

10 As shown in Fig. 33, the write efficiency can
be improved if a plurality of write after records 160
are written in records 301 below the read/write head 309
at physical write positions disposed sequentially in the
direction opposite to the direction of rotation of the
15 disk 308. Furthermore, as shown in Fig. 34, in the case
where two physical write positions are spaced apart by a
predetermined distance or more, the efficiency can be
further improved if the write after process is
intercepted between the two write after records 160
20 because waste time to be occupied by the director 25 and
data transmission lines is eliminated.

Fig. 26 is a detailed block diagram showing
the information processing system of this embodiment.
The different points from the first embodiment shown in
25 Fig. 1 are as follows.

First, the appointed information 3400 from CPU
20 has not the appointed information 5, but has
appointed information 6 and 7.

1 The appointed information 6 appoints the write
data amount. If there is only one filed to be written,
the length of this field 606 is used as the write data
amount. When the director 25 receives the appointed
5 information 6 from CPU 20, the physical write position
on the track of the record 301 to be written can be
calculated before it receives the data from the channel
22. The appointed information 6 may not be provided
necessarily, so the appointed information 6 is shown
10 between parentheses in Fig. 26.

 The appointed information 7 is the information
indicating that the track 300 to be written satisfies
the following structural conditions A to C.

 Condition A ... The record numbers 602 of the
15 records 301 on the track 300 to be written are given in
the ascending order starting from the record number "0"
of the control record 310, each incremented by "1".

 Condition B ... The field 606 other than the
control field 600 contains only the data field 601, and
20 the length of the data field 601 of the record 301 other
than the control record 310 is the same for each record
within the same track.

 Condition C ... The control record 310 is a
standard record. Namely, the field 606 other than the
25 control field 600 of the control record 310 contains
only the data field, and the length of the data field
has a predetermined standard length.

1 If the structural conditions A to C are
satisfied, it becomes possible to calculate the physical
write position on the track 300 of the record 301.

5 The reason why the physical write position can
be calculated is as follows.

10 If the condition A is satisfied, it is
possible to know where is the record 301 to be written
from the start of the track 300, basing upon the record
number 602 from the channel 22 received by the director
15 25. If the conditions B and C are then satisfied, it is
possible to know the length of the field 606 of each
record 301 on the track 300, basing upon the length of
the data received from the channel 22 or the write data
amount contained in the appointed information 6. With
20 the above-described information, it is possible to
calculate the physical position on the track 300 of the
record 301 to be written.

25 Whether or not the track 300 to be written
satisfies the conditions A to C is notified to the
control mechanism within CPU 20. Thus, CPU 20 can
generate the appointed information 7.

30 Another different point from the first
embodiment is that the execution condition c 3410 of the
cache write operation 120 is satisfied if the track 300
35 to be written satisfies the conditions A to C.

40 The following is still another different point
from the first embodiment with respect to the operation

1 of writing the write after data 29 into the disk unit
24.

Specifically, for the write after operation d
3420, the director 25 checks if the record 301 having
5 the record number 602 supplied from the appointed
information 3 is present near within a predetermined
distance from the calculated write position of the
record 301 on the track 300 of the disk unit 24.

Scanning the record near within the predetermined
10 distance from the calculated write position is executed
because the physical position of the record 301 will be
displaced to some degree if a faulty record unable to be
read/written is present on the track 300.

The cache memory 26, directory 28, track table
15 501, empty segment queue head pointer 502, and write
after memory 27 all have the same structure as the first
embodiment, respectively shown in Figs. 6, 8, 10, 11,
and 12.

The dummy control field 1000, the key field
20 pointer 1001, data field pointer 1002, dummy control
field flag 1003 of the segment 400 have all the same
structure as the first embodiment shown in Fig. 7.

However, the key field 607 is not present in
the record 301 of the track 300 satisfying the
25 conditions A to C, so that the key field length 608 of
the dummy control field 1000 is always "0", and the key
field pointer 1001 always takes a null value. Moreover,
the field 606 to be subject to the partial write process

1 contains only the data field 601, so that the dummy
control field 1000, key field pointer 1001, data field
pointer 1002, dummy control field flag 1003, and data
field 601 are all stored in consecutive areas.

5 Fig. 27 shows the structure of the segment
management information 500 of this embodiment. The
difference from the first embodiment shown in Fig. 9
resides in that the segment management information 500
of this embodiment includes the following information.

10 A write position calculation possible bit
2200 ... This bit indicates whether or not the track
300 of the segment management information in concern
satisfies the conditions A to C.

15 A fixed data field length 2201 ... This length
is representative of the fixed length of the data field
601 of the record 301 other than the control record 310.

Fig. 28 shows the structure of the write after
information 1100. The difference from the first
embodiment shown in Fig. 13 resides in that the write
20 after information 1100 of this embodiment includes the
following information.

25 A write after start record number 2300 ... In
this embodiment, if the positions of two write after
records 160 on the track 300 are spaced by a pre-
determined distance or more, the data transfer to the
disk unit 24 is intercepted and the positioning process
is executed to improve the efficiency of the write after
process. Therefore, the record number 602 of the next

1 write after record 160 is set as this write after start
record number.

Record physical position inconsistent
information 2301 ... This information is set if the
5 record 301 is not present at the calculated physical
position.

The structure of the director 25 is similar to
the first embodiment shown in Fig. 14, and is
constructed of the cache partial write part 10, write
10 after schedule part, 11, write after transfer part 12,
and write after error decision part 13. The process
flow for each part is different from the first
embodiment, which will be described below.

Fig. 29 is a flow chart illustrating the
15 processes to be executed by the cache partial write part
10. Similar to the process flow of the first
embodiment, this process flow includes also a process
for the case where the record 301 to be written is
already stored in the cache memory 26.

20 This process flow is executed when a partial
write request is received together with the information
representative of that the track 300 to be written
satisfies the conditions A to C.

This process flow will now be described below
25 while paying attention mainly to the different points
from the first embodiment shown in Fig. 15.

At step 2400, the physical position of the
record 301 on the track 300 is calculated in accordance

1 with the record number received from the appointed
information 3 and the write data amount received from
the appointed information 6.

At step 2401, it is checked if the range
5 determined by the calculated physical position is within
the capacity of one track 300. If not, the process flow
advances to step 2412, and if the range is within the
capacity, it advances to step 2402.

At step 2402, it is checked if the segment 400
10 has been allocated to the track 300 to be written. If
already allocated, the process flow advances to step
2407, and if not, it advances to step 2403.

At steps 2403 and 2404, the track 300 to be
written is allocated with the segment 400 and segment
15 management information 500, and the segment management
information is initialized. These processes are similar
to those at steps 1301 and 1302 shown in Fig. 15.

The processes at the steps 2405 and 2406 are
executed when a partial write request is received for
20 the record 301 not present in the cache memory 26.

These processes are similar to those at steps 1303 and
1304 shown in Fig. 15. After the process at step 2406,
the process flow advances to step 2411.

At step 2407, it is checked if the validity of
25 the write data amount received from the appointed
information 6 can be checked or not. Namely, it is,
checked if the director 25 can check the write data
amount appointed by CPU 20.

1 If the record to be written is the control
record 310, the data field length 602 of the control
record 310 on the track 300 has a specific reference
value because of the condition C. It is therefor
5 possible to check the validity of the write data amount
by comparing the write data amount appointed by CPU 20
with the reference value of the data field 601 of the
control record 310.

10 If the record 301 to be written is the record
other than the control record 310, the data field length
602 of each record 301 of the record other than the
control record 310 is the same because of the condition
B. Therefore, if at least one record 301 other than the
control record is stored in the cache memory 26, then it
15 is possible to check the validity by comparing the write
data amount appointed by CPU 20 with the data field
length of the record other than the control record
stored in the cache memory 26.

1 If the validity check is not possible, the
20 process flow advances to step 2409, and if possible, it
jumps to step 2408.

2 At step 2408, the validity of the write data
amount is checked. If the write data amount is not
valid, the process flow jumps to step 2412 in order to
25 notify an error to CPU 20. If the write data amount is
valid, the process flow advances to step 2409.

3 At step 2409, it is checked if the record 301
to be written is being stored in the cache memory 26.

1 This step is similar to step 1305 shown in Fig. 15. If the record 301 is not being stored, the process flow advances to step 2405, and if stored, it advances to step 2410.

5 At step 2410, the data received from the channel 22 is written in the data field 601 of the cache memory 26.

10 At step 2411, necessary information of the segment management information 500 is updated, and a completion of the write process is notified to CPU via the channel 22, to thereafter terminate the process flow.

15 At step 2412, CPU 20 is notified via the channel 22 of the fact that the write data amount is not valid, to thereafter terminate the process flow.

Fig. 30 is a flow chart illustrating the processes to be executed by the write after schedule part 11.

20 This process flow is executed during the idle time of the director 25.

The process at step 2500 is similar to that at step 1500 of the first embodiment shown in Fig. 16.

25 At step 2501, the smallest record number 602 whose update record pointer 807 does not take a null value is searched from the segment management information 500 corresponding to the object track 300, and set in the write after start record number 2300. Since the write after record 160 is selected in the

1 order starting from the smaller record number 602
because of the condition A, the write process can
proceed in the direction opposite to the rotation
direction of the disk 308 thereby improving the write
5 process efficiency.

At step 2502, a positioning request for the track 300 to be written is issued to the corresponding disk unit 24.

Fig. 31 is a flow chart illustrating the
10 processes to be executed by the write after transfer
part 12.

This process flow is executed when the positioning request issued to the disk unit 24 at step 2502 shown in Fig. 30 has been completed.

15 At step 2600, selected as the write after record 160 to be first written, is the write after record 160 pointed by the update record pointer 807 corresponding to the write after start record number 2300.

20 At step 2601, calculated is the physical write position on the track 300 of the write after record 160 corresponding to the update record pointer 807.

At step 2602, it is checked if the record 301 is being stored within a predetermined range of the
25 calculated physical position. If the record 301 is not being stored, the process flow advances to step 2610, and if stored, it advances to step 2603.

1 At step 2603, the control field 601 of the
stored record 301 is read.

At step 2604, the record number 602 in the
read-out control field is compared with the record
5 number 602 in the dummy control field 1000 or control
field 600 pointed by the update record pointer 807. If
both the record numbers 602 are not coincident, it means
an error so that the process flow advances to step 2612.
If both the record numbers 602 are coincident, the
10 process flow advances to step 2605.

At step 2605, the data field length 603 in
the read-out control field 601 is compared with the data
field 603 in the dummy control field 1000 or control
field 600 pointed the update record pointer 807. If
15 both the data field lengths are not coincident, it means
an error so that the process flow advances to step 2611.
If coincident, the process flow advances to step 2606.

At step 2606, the write after data 160 is
written in the track 300.

20 At step 2607, searched is the update record
pointer 807 having the next large record number 5602
without a null value. If a proper update record pointer
807 cannot be searched, it means that all write after
records 160 for the track 300 in concern have been
25 written, so the process flow advances to step 2613. If
a proper update record pointer 807 can be searched, the
process flow advances to step 2608.

1 At step 2608, it is checked if the distance
to the record 301 pointed by the searched update record
pointer 807 is equal to or larger than a predetermined
value. If the distance is smaller than the predeter-
5 mined value, the process flow returns back to step 2601
to again execute the above-described processes for the
record 301 pointed by the searched update record pointer
308. If the distance is equal to or larger than the
predetermined value, the process flow advances to step
10 2609.

 At step 2609, the positioning request is
issued to the disk unit 24 to thereafter intercept the
write after process. In this case, the record number
602 of the record to be next written is set as the write
15 after start record number 2300, and necessary informa-
tion of the segment management information 500 is
updated.

 At step 2610, the record physical position in
consistent information 2301 is set to thereafter advance
20 to step 2614.

 At step 2611, the field length in consistent
information 1204 is set to thereafter advance to step
2614.

 Steps 2612 to 2614 are similar to steps 1508
25 to 1510 shown in Fig. 17. At these steps 2612 to 2614,
the record number in consistent information 1203 is set,
the segment management information 500 is updated, and

1 the write after processing flag 1200 is reset,
respectively.

Fig. 32 is a flow chart illustrating the
processes to be executed by the write after error
5 decision part 13.

This process flow is executed when an
input/output request is received from CPU 20 via the
channel 22, similar to the process flow of the first
embodiment shown in Fig. 18.

10 At step 2700, it is checked if data is set to
the record number in consistent information 1203, field
length in consistent information 1204 or record physical
position in consistent information 2301, respectively in
the write after information 1100 of the disk unit 24 for
15 which the input/output request was issued. If data is
not being set to all of the information, the process
flow is terminated. If data is being set to any one of
the information, the process flow advances to step 2701.

At step 2701, an error is notified to CPU 20.

20 Next, the fourth embodiment will be described
with reference to Figs. 35 to 41. According to the
fourth embodiment, if the record 301 to be written is
not being stored in the cache memory 26, the director 25
makes a decision, in accordance with the information
25 held by the control unit 25, that the data is to be
written in the cache memory 26 and the write process is
completed at this stage. Moreover, the efficiency of
the write after process is intended to be improved by

1 calculating the physical write position on the track 300
of the record 301 to be written.

The information held by the control unit 23 is
the information representative of whether each track 300
5 satisfies the conditions A to C.

Fig. 35 is a detailed block diagram showing
the information processing system of this embodiment.
The different points from the third embodiment shown in
Fig. 26 are as follows.

10 First, the appointed information 3500 from CPU
20 has not the appointed information 7.

Second, the write after memory 27 stores the
information representative of whether or not each track
300 of the disk unit 24 satisfies the conditions A to C.

15 Third, the execution condition C 3410 is
checked by the director using the information stored in
the write after memory 27.

The cache memory 26, directory 28, segment
management information 500, track table 501, and empty
20 segment queue head pointer 502 all have the same
structure as that shown in Figs. 6, 8, 27, 10 and 11,
respectively.

Fig. 36 shows the structure of the write after
memory 27 of this embodiment. The different point from
25 the third embodiment shown in Fig. 20 is as follows.
Instead of the write after track information a 1700,
there is provided write after track information b 2800
for each disk unit 24.

1 Fig. 37 shows the structure of the write after
track information b 2800. The write after track
information b 2800 includes the following information
provided for each track 300 of the disk unit 24.

5 Track state b 2900 ... Information
representative of whether or not the track 300 in
concern satisfies the conditions A to C, or
representative of that it is not certain whether the
track 300 satisfies the conditions.

10 Fixed data field length information 2901 ...
Information of the length of the data field 601, the
length being the same for all records 301 if the track
300 satisfies the conditions A to C.

Fig. 38 shows a state transition of the track
15 state b 2900. Transition between the states b 2900 is
executed in the similar manner as the track information
a 1800 of the second embodiment shown in Fig. 22.
Specifically, when a partial write request is received
during a state 401 that it is not certain whether the
20 track 300 satisfies the conditions A to C, it is checked
if the track 300 satisfies the conditions A to C, and
the check result is stored in the track state b 2900.
When a format write request is received for the track
300, the track state b 2900 is set to the state 401 that
25 it is not certain whether the track 300 satisfies the
conditions A to C.

The order of storage of the track information
b 2900 and fixed data field length information 2901 is

1 in the order of track number, similar to the track
information a 1800 of the second embodiment shown in
Fig. 22.

5 The structure of the director 25 is similar to
the second embodiment shown in Fig. 23.

The process flows for the write after schedule
part 11, write after transfer part 12, and write after
error decision part 13 are similar to those of the third
embodiment shown in Figs. 30 to 32, respectively.

10 However, the process flows for the cache partial write
part 10, write after track information management part a
14, and write after track information management part b
15 are different, so the description therefor will be
given below.

15 Fig. 39 is a flow chart illustrating the
processes to be executed by the cache partial write part
10. Similar to the process flow of the first embodiment
shown in Fig. 15, this process flow includes also a
process for the case where the record 301 to be written
20 is already stored in the cache memory 26.

This process flow is executed when the
director 25 receives a partial write request from CPU 20
via the channel 22, and the track state b 2900 of the
track to be written indicates the state 402 that the
25 track satisfies the conditions A to C.

At step 3000, it is checked if the write data
amount supplied from CPU 20 is valid. In this
embodiment, even if the segment 400 is not allocated to

1 the track 300 to be written, it is possible to check the
validity of the write data amount from the value in the
fixed data field length information 2901. If the write
data amount is not valid, the process flow jumps to step
5 3011. If the write data amount is valid, it advances to
step 3001.

The processes at step 3001 and following steps
are similar to the process flow shown in Fig. 29.
Namely, steps 3001 to 3007 correspond to steps 2400 to
10 2406 shown in Fig. 29, and steps 3008 to 3011 correspond
to steps 2409 to 2412 shown in Fig. 29.

Figs. 40A and 40B are flow charts illustrating
the processes to be executed by the write after track
information management part. The different points from
15 the process flows of the third embodiment shown in Figs.
24A and 24B reside in that the process flows shown in
Figs. 24A and 24B deal with the write after track
information a 1700, whereas the process flow shown in
Figs. 40A and 40B deal with the write after track
20 information b 2800.

The process flow shown in Fig. 40A is executed
at the time similar to the process flow shown in Fig.
24A.

At step 3100, there is issued a positioning
25 request for the track 300 to be written.

The process flow shown in Fig. 40B is executed
when the positioning request issued at step 3100 has
been completed.

1 At step 3101, all records 301 on the track 300
to be written are read to check if the track satisfies
the conditions A to C.

5 At step 3102, the check result at step 3101 is
stored in the track state b 2900 for the track 300. If
the conditions A to C are satisfied, the length of the
data filed 601 is set in the fixed data field length
information 2901, to thereafter terminate the process
flow.

10 Fig. 41 is a flow chart illustrating the
processes to be executed by the write after track
information management part b 15. The difference
between the process flow shown in Fig. 41 and the
process flow of the third embodiment shown in Fig. 25 is
15 that the former flow deals with the write after track
information a 1700 whereas the latter flow deals with
the write after track information b 2800.

20 The process flow shown in Fig. 41 is executed
at the time similar to the process flow shown in Fig.
25.

25 At step 3200, the track state b 2900 of the
track 300 to be written is reset to the state 401 that
it is not certain if the track 300 satisfies the
conditions A to C.

30 In the third and forth embodiments, the
continuity of positions of records to be stored in the
cache memory 26 has not been considered at all.

35 However, if there is introduced a restriction
that records 301 on the track 300 are physically

1 consecutive positions should be stored in the segment
also at physically consecutive positions, the cache
control can be executed in a more simple manner. Such a
restriction is called a consecutive storage restriction.

5 For example, as shown in Fig. 42, it is
assumed that a record m 3600 and a record n 3601 are
present on the track 300 at physically consecutive
positions. In such a case, it often occurs that CPU 20
requests to consecutively read the record m 3600 and
10 record n 3601 on the track 300 at the physically
consecutive positions. If the record m 3600 and record
n 3601 are stored in the segment 400 consecutively, the
director 25 is allowed to simply read a certain area in
the segment 400 and send the data to CPU 20. Namely, in
15 transferring the record n 3601 from the control unit 23
to CPU 20, it is not necessary to execute a process of
referring to the record pointer n 3603 of the segment
management information 500.

In order to be subject to the consecutive
20 storage restriction, it is sufficient if the director 25
is permitted to terminate the write process when the
data has been written in the cache memory 26, on
condition that the following consecutive storage
conditions 1 to 3 are satisfied.

25 Consecutive storage condition 1 ... The record
301 on the track 300 to be written is not being stored
in the cache memory 26. The consecutive storage
restriction can be met in this case because the director

1 25 stores a record k 4300 to be written in a newly
established segment 400, as shown in Fig. 43A.

Consecutive storage condition 2 ... The record
301 to be written is the same record 301 already stored
5 in the cache memory 301, while meeting the consecutive
storage restriction. The consecutive storage
restriction can be met in this case because the data is
written in an already stored record k 4300 to update the
contents of the record, as shown in Fig. 43B.

10 Consecutive storage condition 3 ... The record
301 to be written has the record number 602 larger by 1
than the maximum record number of the record 301 on the
track 300 already stored in the cache memory 26. In
other words, the record number 602 of the record 301 to
15 be written is consecutive with that of the record 301
already stored in the cache memory 26. The consecutive
storage restriction can be met in this case because the
director 25 causes a record k 4300 to be stored in the
area after the record 301 (..., k-1) already stored in
20 the segment 400, as shown in Fig. 43C.

The consecutive storage restriction is
applicable both to the case where CPU 20 supplies the
information representative of whether the track 300 to
be written satisfies the conditions A to C (the third
25 embodiment) and to the case where the control unit 23
holds for each track 300 the information representative
of whether the track 300 to be written satisfies the
conditions A to C (the fourth embodiment). When the

1 consecutive storage restriction is introduced, only the
segment management information 500 changes.

Fig. 44 shows the structure of the segment
management information 500 introducing the consecutive
5 storage restriction according to the fifth embodiment.
The different point from the third embodiment shown in
Fig. 27 is that an intra-cache maximum record number
3700 is provided. This intra-cache maximum record
number indicates the maximum record number 602 of
10 records 301 stored in the cache memory 26.

The process flows shown in Figs. 29 to 32, and
Figs. 39 to 41 are applicable to this embodiment,
excepting that the process flows by the cache partial
write part 10 shown in Figs. 29 and 39 are executed at
15 different times. Namely, the process flows are executed
when the track 300 to be written satisfies the
conditions A to C and the consecutive storage conditions
1 to 3.

According to the cache control method and
20 apparatus, even if the record subjected to a partial
write process is not being stored in a cache memory, it
is possible to terminate the write process at the time
when the data has been written in the cache memory.

Accordingly, speeding up the write process using a cache
25 memory is possible for a wide range of applications.
Furthermore, the efficiency of the write process can be
improved by calculating the physical position of a
record.